Energy Audit and Optimization for "Arches etc."

By
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Bachelor of Science in Industrial Engineering

California Polytechnic State University
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Executive Summary

Arches etc. is a San Diego business, which specializes in the manufacture, distribution, and installation of custom designed doors, windows, mouldings, and hardware. Due to the recent economic downturn, which has hindered the construction industry, Arches etc. believed that an analysis and optimization of their energy usage would provide additional assistance towards their goal to lower overhead and maintain current operations.

To begin this task, a comprehensive energy audit was conducted to establish an initial state from which to base improvements. Arches etc.'s current monthly utility bill averages $996, which solidifies the accuracy of this project's performed energy audit, estimating their monthly consumption to be $985. With this energy audit as baseline to build upon, several aspects of their facility were analyzed, including: Manufacturing Processes, Equipment Capacity, Equipment Runtime, and Equipment Efficiency. After developing a collection of proposed improvements based upon these areas, the economic justification of each improvement was evaluated. Free energy saving improvements, or those that did not require an initial investment, resulted in an estimated annual savings of $2,000. Additional savings were found through equipment investment opportunities, resulting in annual savings of $958. Investment opportunities were evaluated on their payback period and Net Present Value. Investments that offered a positive NPV were included in the final recommendations. It has been recommended to Arches etc. that through implementation of these various energy saving improvements they can reduce their monthly electric utility bill by at least 26%. This reduction has the capability of bringing their current monthly electric bill from $996 to $739. To complement these improvement recommendations, Arches etc. has also been provided a series of observational energy efficient guidelines to conserve electricity throughout their facility.

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Background

Energy costs have increased dramatically over the most recent decades. Not only has the price per gallon of gasoline shown exponential growth, but the price per kilowatt of electricity has also soared. According to the California Energy Almanac the states average retail electricity price from 1982 to 2009 has increased from 7.7 cents per kilowatt-hour to 13.3 cents/kWh, nearly a 73% increase. Commercial businesses rely on this energy to run their daily operations and to add value to their product. With this high overhead cost, it has now become even more essential that businesses evaluate their energy consumption and optimize their use of this dependable, yet costly resource.

Today, there are several large corporations that profit from solving these building and energy usage problems. Longstanding companies, such as Johnson Controls Inc. maintain one third of their business in the building efficiency market. They “provide solutions for operating buildings effectively and efficiently to increase a building's energy efficiency and operational performance.” According to Johnson Controls energy efficiency helps control rising energy costs, reduces environment footprints, and increases the competitiveness of buildings.

Arches etc., founded in 1971, has lasted the volatile years of the residential construction industry. Their almost unbeatable level of experience in their construction trade competitively places them as a leader of the niche high-end market in their region. Specializing in the manufacturing, distribution, and installation of custom designed entry doors, windows, mouldings, and hardware, Arches etc. has vastly contributed to the establishment of Rancho Santa Fe, Ca as a premier and luxurious home destination. However, due to the straining economy, which has directly affected the construction industry. Arches etc. has been forced to scale back their operations to combat the extended years of decreasing revenue. With Arches etc. locked in to long-term lease agreements, they have been forced to lower fixed cost expenses, starting with lowering the number of employees. At this time, Arches etc. is still looking for alternative means to lower their overhead, yet continue their current operations. Arches etc. believes that an analysis and optimization of their energy usage would provide additional assistance towards their goal to lower overhead and continue operations during this economic downturn.

Factors considered:

- Machine operations and processing
- Standby equipment
- Lighting
- Heating Ventilation and Air Conditioning
- Repetitive tasks
- Compressors
- Machine Size and Capacity

Motivation

Energy usage plays as a key factor in a business's overhead costs. Some of their usage can be contributed to fixed energy usage but other usage can be attributed to business variable cost or product unit variability. The key motivation is that a lot of businesses simply do not take the time to analyze their energy usage. With more efficient technology available, outdated machines or electric dependent items are affecting businesses energy bills, and ultimately their profit margin. There is currently an increasing movement of companies to go "green" or become "sustainable". Businesses want to capture this public image and are therefore turning to more efficient energy usage. The added bonus that most companies fail to recognize is the new and lower overhead cost associated with their efficient implementation.

Within the past year energy efficiency has gained even more momentum due to President Obama's stimulus bill. Outlined in the President's bill is $43 billion allotted to energy and $111 billion to aid in infrastructure and sciences. However, arguably the most direct benefit for increased energy efficient building operation is the allocation of rebates of up to 30 percent of new-energy-project costs. This influential revelation has dramatically changed the affordability, awareness, and competitiveness of energy efficient operations and machinery.

As far as a personal motivation, over the past few years of my education I have increasingly become more and more interested in efficient energy use, particularly the solar industry. Due to this fascination, I had hoped to pursue a related career upon my graduation and since starting this project I have been offered and accepted a career within Johnson Controls Building Efficiency division. With the completion of this senior design project I feel that I have gained an initial insight into the field of energy efficiency and prepared myself for my career within this industry.

Literature Review

To assist with the completion of this project, a comprehensive literature review of the Industrial Engineering topics which were essential to the development of this study was conducted. Focused areas of research review included: Work Study, Industrial Costs and Controls, and Engineering Economics. Further, appropriate topics of Energy Efficiency and Energy Audits were needed for this project, and in turn were introduced and studied within this literature review.

Work Study

> *"Work study is the systematic examination of the methods of carrying on activities so as to improve the effective use of resources and to set up standards of performance for the activities being carried out"* (Kanawaty, 1992)

The essential reason behind the tools and framework of work-study is the measurement of productivity.

Productivity = Output / Input

Outputs of an enterprise are characteristically define as the products and/or services rendered to the customer. On the other hand, inputs are typically the resources necessary to produce this desired output. Inputs can be classified into the following:

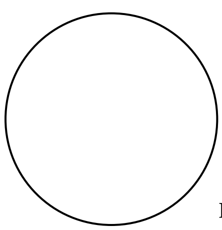
Land and Building
Materials
Energy
Machines and Equipment
Human Resources

For the purpose of this examination of Arches etc., the outputs of particular interest to this design were focused primarily on *energy, along with machines and equipment*. These methods of work-study, specifically a focus on productivity, provided the necessary attention to the inputs and outputs of Arches etc.

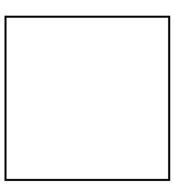
One key aspect to measuring the productivity of an enterprise is to develop an operational process chart of their existing processes. These graphical tools provide industrial engineers the opportunity to identify tasks that may be likely candidates for areas of improvement.

Operations Process Chart

> *"A graphic, symbolic representation of the act of producing a product or providing a service, showing operation and inspections performed or to be performed with their sequential relationships and materials used. Operation and inspection time required and location may be included."* (Aft, 2000)



An operation is classified as an activity or subdivision of a process that modifies a material, part or particular product in the given production. In the Operations Process Chart the *operation* is graphically represented by a circle.



The alternative activity to an operation is the inspection. Graphically designated as a square, an inspection represents the process that involves the observation and comparison of the quality of previous operations to quantified quality standards.

Operation process charts generally follow several other noteworthy conventions:

- Horizontal Lines demonstrate where the material enters
- Vertical Lines demonstrate the sequential steps
- A single, short horizontal line demonstrates the entrance of a purchased material
- Flow of the chart follows a left to right and top to bottom orientation

Once an operation process chart was accurately developed, the individual processes were evaluated for opportunities of improvement. Various phases of each operation were considered: (Barnes, 1980)

Materials

- Can cheaper materials be used?
- Is the material utilized to its full extent?
- Can some use be found for scrap and rejected parts?

Materials Handling

- Can the number of times the material is handled be reduced?
- Can the distance moved be shortened?

Machine

- Can the operation be eliminated?
- Can the work be done in multiple?
- Can the part be prepositioned for the next operation?
- Can interruption be reduced or eliminate?
- Is the machine in good working condition?

Working Conditions

- Are the light, heat, and ventilations satisfactory for the job?

An operation process chart, focused on the most crucial activities of Arches etc. was an essential tool in this project. These charts provided a graphical depiction of their most detailed activities. From these depictions, processes were able to be incrementally analyzed and concentrated areas of improvements were recognized

Energy Audit Definition

"An energy audit may be considered similar to the monthly closing statement of an accounting system. One series of entries consists of amounts of energy which were consumed during the month in the form of electricity, gas, fuel, oil, steam, and the second series lists how the energy was used: how much for lighting, in air-conditioning, in heating, in process, etc. The energy audit process must be carried out accurately enough to identify and qualify the energy and cost savings that are likely to be realized through investment in an energy saving measure." (Thumann, 1998)

Types of Energy Audits

Walk-Through – Least costly of types and identifies possible changes to current energy usage. An initial visual inspection is made of the building to determine opportunities and savings within the areas of maintenance and operations.

Mini-Audit – This audit requires measurements and appropriate tests to quantify the amount of energy used. These calculations are used to then determine the economics for changes.

Maxi-Audit – This type of audit is a continuation of the mini-audit. It is composed of an evaluation of the energy used in each operation or function within the facility. Areas of analysis include: lighting, manufacturing, processes, and building maintenance. This type of audit usually requires a model analysis, which typically consists of a computer simulation. With this simulation, the year around energy patterns can be predicted. Sometimes this analysis will even take into account numerous outside variables such as weather data.

For the scope of this project a combination of the three types of audits was the most applicable. An initial Walk-Through was used to identify specific energy saving opportunities. After identified, these opportunities were evaluated with appropriate tests to quantify the amount of energy used. Further, these opportunities were analyzed based on their degree of function and operation within the facility.

Energy Efficiency

The process for achieving energy efficient operation of a commercial building is comprised of two considerations, each consisting of three subsets. (Herzog, 1997)

Start-Up Activities (Identify and Quantify Energy Consumers)

- Identify Energy Consuming Devices
- Estimate Electrical Energy Use
- Estimate Fuel Energy Use

Ongoing Activities (Monitor and Continually Improve Operating Efficiency)

- Measure Actual Energy Use
- Determine Required Energy Use
- Minimize the Difference Between Actual and Required Energy Use

This organized process kept the focus of the project on schedule and on track with its original concentration. Each of these tasks was directly aligned with the guidelines and definitions of an energy audit.

Major Energy Conservation Opportunities Considered (Dubin, 1976)

- Maintain Lower Indoor Temperatures During Heating Season
- Reduce The Rate of Infiltration (Cracks, Doors, Windows, and Joints)
- Replace Old and Inefficient Energy Using Machines
- Turn Off All Cooling Devices During Unoccupied Hours (Fans, Pumps, and Condensers)
- Reduce Quantity of Outdoor Air Ventilation
- Reduce Solar Heat Gain Through Windows (East/West, Shading, or Awnings)
- Utilize Daylight to Reduce Lighting Load
- Turn off Lights in Unoccupied Areas
- Reduce Illumination Levels to Reduce Lighting Load

These suggestions played a crucial role in determining areas of inefficient energy usage. As these areas were each targeted, they were analyzed for feasibility of implementing an applicable solution.

Industrial Costs and Controls

Accounting can most closely be related to the idea of scorekeeping. Business owners and managers place a heavy burden on their performance or "score" of their company; similar to coaches who are interested in the final score of their contest. Managers and coaches alike use the score to change tactics and strategies, and ultimately make better decision to improve overall performance. (Riggs, 2004)

Accounting can be summarized into five distinct actions:

1. Observe: The subjects of the entity that are of monetary significance must first be observed.
2. Measure: The observations of the entity must be measured for their value in monetary units.
3. Record: A sequential log of the measurements must be recorded.
4. Classify: The recorded data must be classified in order for the information to be legible.
5. Summarize: With classified data, the information must be summarized for decision makers to evaluate the business's direction.

These essential accounting steps were beneficial in creating to the financial evidence proving the feasibility of recommended improvements. As a result, Arches etc. has the concrete numbers required once the recommendations are put into the decision maker's hands

Engineering Economics

The essence of engineering can broadly be described as the applications to solve human needs and wants. However, these solutions are not created without cost. There are several classifications of cost that will come into play when analyzing the financial impacts of a solution. (Thuesen, 2001)

First Cost: the initial cost of capitalized property, including, transportation, installation, and other related initial expenditures

Operations and Maintenance Cost: the group of costs experience continually over the useful life of the activity

Fixed Cost: the group of costs involved in an ongoing activity whose total will remain relatively constant throughout the range of operational activity

Variable Cost: the group of costs that vary directly to the level of operational activity

These differing classifications of cost are a definitive element to the understanding of this project. Each type of cost plays a factor in the decision-making and analysis of operations improvement and even financial feasibility. When calculating the financial impacts of opportunities the distinction between these cost classifications was required.

Companies are constantly searching for assets that will potentially provide a lucrative future. It was important to use the appropriate financial decision making techniques when making these investments. The key to making financially sound investments was to consider the net present value of that investment. (Brealey, 2008)

Present Value (PV) = The value of future dollars adjusted for interest and converted into today's dollars

Net Present Value (NPV) = The present value of a future investment subtracted by the required investment amount

Example: A real estate agent suggests that a home, currently priced at $370,000, could fetch $420,000 one year from now.

If you were to invest $400,000 this year at a 5% interest rate, next year your investment would turn into $420,000. This $400,000 is the present value of the $420,000 dollar potential real estate sale.

Therefore, the Net Present Value of this investment opportunity is the present value, of the year from now sale price, subtracted by the currently required investment amount.

NPV = $400,000 - $370,000 = $30,000

In this case, the investment is a lucrative opportunity, due to the positive NPV ($30,000).

This example demonstrates the importance of considering the time value of money when making investment decisions. These Net Present Value decision-making techniques assisted with making financially accurate recommendations to Arches etc.

Design

The overall approach of this project can be subdivided into four sequential steps: Energy Audit, Operation Documentation, and Improvement Development. Each of these three steps worked towards the goal of creating financially feasible recommendations for Arches etc.

Energy Audit

In following the procedures of a mini-audit, the first step accomplished was identifying all of the facility's energy consuming devices. Each device was categorized into one of four general classifications: Office, Heating and Cooling, Lighting, or Machinery. After identifying all devices, the electrical demand of each item was recorded. When electricity usage was not documented for a device, operating wattage and standby wattage were both determined through testing with a handheld Kill A Watt tool. With the electrical requirements of each piece of equipment in hand, the next step was to estimate the respective run times. In many cases, the run time was easily determined by basing it on the daily operation hours of the facility. Office lighting and computer usage are two examples that were determined by these means. However, in the cases of most manufacturing equipment, time studies were necessary to determine appropriate run time estimation. Time study data was collected for each of these machines for the run time of producing a single product (cycle). For the scope of this energy audit estimation, 25 observations (cycles) were recorded for each machine and each operator was assumed to have an operator rating of 100 (Table 4, Appendix A). The mean run times per cycle were then multiplied by the daily production rate to estimate the daily operational run times. With all daily run times then calculated in kWh, the figures were then scaled for monthly utility usage, assuming 22 workdays per month. This energy audit established an initial state for the system and was then compared to Arches etc. actual monthly utility bill.

Operation Documentation

In order to identify areas of improvement within Arches etc.'s operational processes, it was beneficial to develop flow process charts of their current system. First a general flow process chart was created, outlining the electricity dependent machines used in their daily manufacturing process. From this outline, a more detailed flow process chart was developed for each machine in the system. These charts detailed the individual and finite tasks involved in the operation of each machine. The flow process chart for the planer is shown to the right, Figure 1. The complete series of flow process charts and their improvised counterparts reducing runtime can be seen in Figures 4-6 in Appendix B. This breakdown and structuring of Arches etc's manufacturing processes provided the necessary assistance in pinpointing improvements to reduce machine runtime.

Improvements

After completing the energy audit and developing the appropriate documentation of the manufacturing processes, improvements could be identified. Initial attention was given to the greatest energy consuming devices, as they could provide the most gains in energy reduction. One specific area of focus was excess runtime and standby time. Using the energy audit as

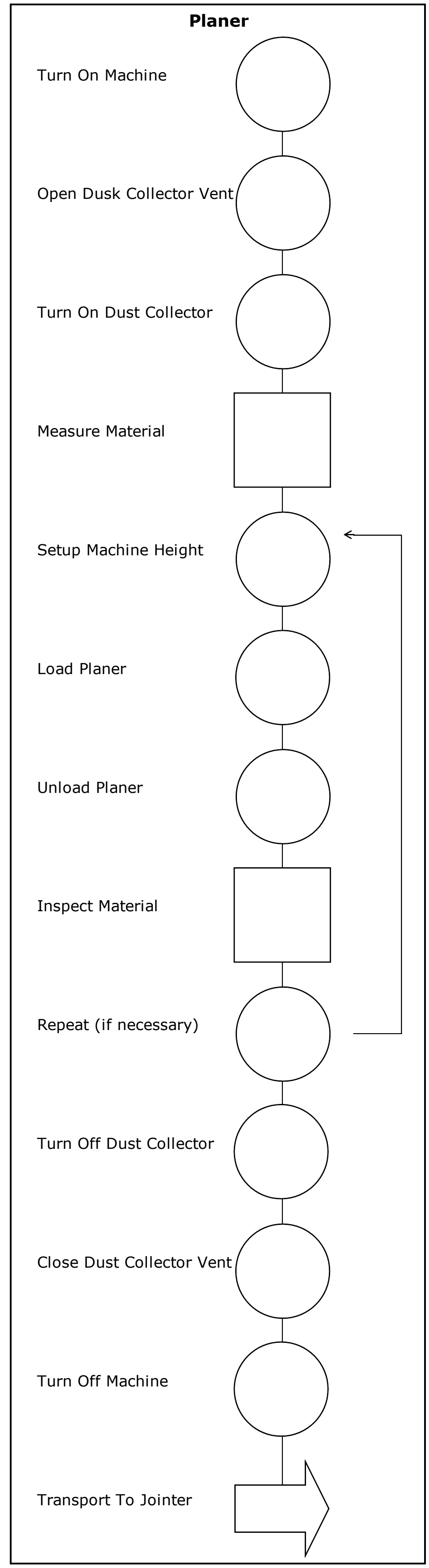


Figure 1 - Flow Process Chart: Planer

reference, run times that were greater than Arches etc.'s daily operation hours were evaluated for wasted energy usage. Further, energy requirements of heavy energy consuming devices were compared to newer and more modern, sometimes more efficient devices. Instances of wasted energy that were observed while in the facility were also further studied at this point. Another tactic for developing improvements was to optimize the finite machine tasks with the goal to decrease runtime. Many reductions in electricity usage were possible with simply reordering the finite tasks of the documented flow process charts.

Methodology

After developing a series of improvements, it was time to consider the financial feasibility of each recommendation. Each proposed improvement was evaluated on its impact to Arches etc. energy usage and resulting monetary adjustment to their monthly utility bill. It was essential to fully analyze the metrics of each correction to their system, in order to provide Arches etc. sufficient evidence to contemplate each final recommendation.

Economic Analysis

To estimate the savings of each improvement, the effected cells, such as reduced runtime or wattage, were changed in the original energy audit calculations. The new reduced electricity cost was then subtracted from the current electricity cost of that machine. These savings were then multiplied over 12 months to calculate savings per year. It is important to note that several improvements were correlated to the runtime of numerous machines, such as the dust collectors. Reductions for these runtimes consisted of the summation of each dependent machine multiplied by the estimated reduction percentage. In the case of proposed improvements requiring investments, payback periods on the initial investment cost were calculated based on their respective savings per year. Further, to determine the validity of each proposed investment, the future cash flows of savings were converted to calculate the NPV of each investment. For NPV calculations a discount rate of 6% was assumed. This interest rate of comparable investment yields in the financial markets was used to discount all proposed investment's future cash flows. Also, the life of each investment and its provided cash flows was assumed to be 10 years. Analyzed investments that resulted in a positive NPV are included in the final recommendations to Arches etc.

Results & Discussion

As seen in the results of the conducted energy audit (refer to Table 3, Appendix A), Arches etc.'s monthly utility bill was estimated at $985.31. Considering that Arches etc.'s current monthly utility bill has average $996 over the most recent 12-month period, the developed energy audit was assumed to be an accurate and credible initial state from which to develop improvements.

Table 1 - Free Improvements

"Free" Energy Saving Improvements					
Improvement	**Equipment Impacted**	**Expected Reduction**	**Current kWh/Yr**	**Expected kWh/Yr**	**Savings Per Year**
Power Down Computers During Off Hours	8 Desktop Computers	39.6%	10707.8	6467.51	$424.03
Power Down Monitors During Off Hours	8 Computer Monitors	40.4%	4815.3	2869.92	$194.54
Power Down Compressors During Off Hours	Compressor Large and Small	30.0%	42372.0	29660.40	$1,271.16
Re-order Process: Postpone Powering On of MFG Equip.	Table Saw Metal, Table Saw Wood, Planer 1, Planer 2, Belt Sander, Jointer	15.0%	12091.2	10277.52	$181.37
Re-order Process: Postpone Powering On of Dust Collector	Dust Collector 1 and 2	10.0%	5682.6	5114.34	$56.83
				Total "Free" Savings Per Year	$2,127.92

Resulting improvements were categorized into one of two classifications: Free Improvements or Investment Improvements. "Free" Improvements are mainly simple process and operational changes to Arches etc. that do not require an investment to be implemented. These Free Improvements as seen above in Table 1, accounted for $2,127 per year. The second group of savings, Investment Savings, are demonstrated in next page below in Table 2. These improvements contributed to almost $1,000 per year in utility bill savings.

Table 2 - Investment Improvements

Investment Energy Saving Improvements						
Investment Amount	**Quantity**	**Description**	**Savings Per Year**	**NPV (6% IR)**	**Payback Period (Years)**	**Decision**
$25	4	Motion Activated Lights - Stock Room	$238	$1,653	0.42	Yes
$2,000	1	2.5 Ton Central AC Unit (15 SEER)	$453	$1,334	4.41	Yes
$800	2	20.3 Cu. Ft. GE Refrigerator (Energy Star)	$267	$353	6.00	Yes
			Savings Over 10 Years	$9,581	**Avg Per Year**	$958

Demonstrated in the Equipment Improvement calculations (refer to Table 4, Appendix A), the savings contributions from each machine can be traced back to its source of improvement. Savings per year rounded out at over $3,000 as result of either runtime reduction or an investment purchase of more energy efficient equipment requiring less wattage.

With the implementation of these final recommendations, Arches etc. should expect savings of at least $257 on each monthly utility bill, or a 26% reduction from their current average bill.

To further reduce their monthly utility bill, these observational energy efficiency and kWh saving recommendations should be followed:

- Set Office Thermostat to 68 Degrees In Heating Season/76 Degrees In Cooling Season
- Substitute Fans Over Air Conditioning Whenever Possible
- Install Pull Down Shades on Showroom Multifold Doors
- Reduce The Rate of Infiltration (Cracks, Doors, Windows, and Joints)
- Install Door Closers to Reduce Outdoor Air Ventilation
- Utilize Daylight to Reduce Office Lighting Load
- Turn off Lights in Unoccupied Areas

Summary & Conclusions

Due to the economic downturn, Arches etc. has been forced to scale back their operations in order to combat decreasing revenues. In light of their current situation, they wanted an analysis and optimization of their energy use in order to decrease their monthly utility bill and in return reduce overhead cost.

To establish an initial state from which to base improvements upon, a comprehensive and accurate energy audit was conducted. With this energy audit as baseline to build upon, several aspects of their facility were analyzed, including: Manufacturing Processes, Equipment Capacity, Equipment Runtime, and Equipment Efficiency. After developing a collection of proposed improvements, the economic justification of each improvement was evaluated. Investment opportunities that resulted in a positive NPV were included in the final recommendations.

- Free Energy Saving Improvements = Annual Savings of $2,192
- Investment Energy Saving Improvements = Annual Savings of $958
    - Estimated Investment Required to Meet Reduction = $3,700
- Monthly Utility Bill Reduced From $996 to an Estimated $739
    - Savings of $257 or 26% Reduction

The analytical procedures that were developed and followed for this project could provide similar savings to businesses other than Arches etc. Most businesses have not focused enough of their attention on their wasteful energy use practices. With this notion in mind, through a thorough analysis and mindful determination to achieve savings, most small to medium sized businesses should find comparable savings to Arches etc.'s 26% utility bill reduction.

Appendix A

	Task Name	Duration	Start	Finish	Predecessors
1	Identify Energy Consuming Devices	3 days	Mon 1/4/10	Wed 1/6/10	
2	Record Device Specifications	6 days	Thu 1/7/10	Wed 1/13/10	1
3	Estimate Monthly Costs	3 days	Thu 1/14/10	Mon 1/18/10	2
4	Estimate Fuel Usage and Costs	3 days	Tue 1/19/10	Thu 1/21/10	3
5	Determine Actual Energy Usage	4 days	Fri 1/22/10	Wed 1/27/10	4
6	Identify Operations of Improvement	5 days	Thu 1/28/10	Wed 2/3/10	5
7	Create Operations Process Chart	5 days	Thu 2/4/10	Wed 2/10/10	6
8	Identify Energy Conservation Opportunities	5 days	Thu 2/11/10	Wed 2/17/10	7
9	Develop Recommended Improvements	10 days	Thu 2/18/10	Wed 3/3/10	8
10	Calculate Financial Feasibility of Improvements	3 days	Thu 3/4/10	Mon 3/8/10	9
11	Evaluate Impact of Improvements on Balance Sheet	3 days	Tue 3/9/10	Thu 3/11/10	10
12	Format Final Report	2 days	Fri 3/12/10	Mon 3/15/10	11
13	Senior Project Submittal	2 days	Tue 3/16/10	Wed 3/17/10	12

Figure 2 - Gantt Chart Tasks

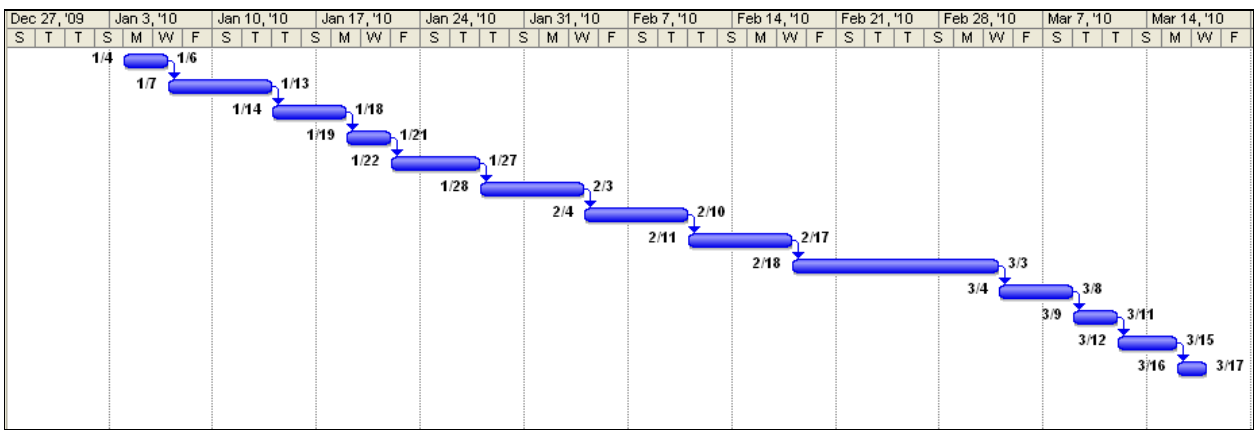


Figure 3 - Gantt Chart Schedule

Table 3 - Arches etc. Energy Audit

	Qty	Hrs/day	Watts	kWh
Office				
Desktop Computer	8	16.9	300	40.560
Monitors	8	11.4	200	18.240
Fax	2	3.5	175	1.225
Copy Machine	1	2.2	420	0.924
Phones	10	24.0	5	1.200
Microwave	2	1.9	600	2.280
Refrigerator	2	12.8	540	13.824
Coffee Maker	1	0.8	800	0.640
Printer	2	2.8	250	1.400
Heating/Cooling				
3.5 Ton Central AC (10 Seer)	1	7.8	4200	32.760
40 Gallon Water Heater	1	3.6	4500	16.200
Lighting				
Flourescent (Warehouse, Office)	108	10.2	40	44.064
Flourescent (Stock Room)	24	10.2	40	9.792
Hanging	3	8.9	100	2.670
Machinery				
Bandsaw 36"	1	1.1	3500	3.850
Bandsaw 24"	1	1.5	2200	3.300
Bandsaw 14"	1	1.5	1100	1.650
Tablesaw Metal	1	2.3	5500	12.650
Tablewsaw Wood	1	2.2	4500	9.900
Chopsaw Metal	1	0.9	3100	2.790
Chopsaw Wood	1	0.9	2300	2.070
Belt Sander	1	2.7	3500	9.450
Edge Sander	1	2.1	2250	4.725
Jointer	1	1.4	750	1.050
Drill Press	1	1.3	400	0.520
Compressor Large	1	13.0	7500	97.500
Compressor Small	1	12.0	5250	63.000
Vaccuum Press	1	2.8	250	0.700
Table Router	1	0.6	1100	0.660
Hand Router	1	1.8	750	1.350
Recharge Batt.	8	6.2	220	10.912
Planer 1	1	1.3	6000	7.800
Planer 2	1	1.1	4500	4.950
Scroll Saw	1	0.9	260	0.234
Grinder 1	1	0.2	350	0.070
Grinder 2	1	0.2	400	0.080
Palm Sander	1	2.2	250	0.550
Hand Belt Sander	1	2.3	350	0.805
Dust Collector 1	1	4.8	3500	16.800
Dust Collector 2	1	2.1	2250	4.725
		Total kWh/Day		447.87
		Price/kWh		$0.10
		Monthly Bill		$985.31

Table 4 - Time Study Observation Form

Time Study Observation Form						
		Observer:	Ross Dixon			
		Date:	12/14/09 - 12/18/09			
	Run Times/Cycle (sec)					
Operator	**Pete**	**Jose**	**Cesar**	**Brian**	**Jose**	**Cesar**
obs #/ Operation	**Planer**	**Tablesaw**	**Jointer**	**Belt Sander**	**Edge Sander**	**Router**
1	36.9	66.3	33.2	89.3	54.0	11.8
2	43.3	61.2	46.9	91.2	62.1	14.6
3	36.8	75.3	34.5	77.6	63.3	21.3
4	35.6	71.1	40.3	75.5	69.8	15.3
5	32.4	68.5	44.6	87.3	54.3	16.3
6	29.7	59.6	28.5	89.4	78.9	14.5
7	46.1	85.3	35.7	71.5	72.0	21.3
8	41.1	72.7	31.5	92.2	65.5	16.0
9	35.5	81.0	45.1	90.0	64.9	13.4
10	38.6	56.6	46.3	71.3	72.3	25.6
11	44.8	69.9	42.7	69.3	62.1	22.0
12	42.7	62.2	39.8	75.8	54.6	19.4
13	28.0	58.6	41.2	65.9	81.1	16.7
14	33.7	69.7	52.5	72.3	64.4	21.3
15	45.5	71.2	46.7	84.6	68.3	14.7
16	46.1	54.4	50.0	72.8	51.7	15.9
17	41.8	62.3	38.8	73.9	53.6	12.6
18	31.3	69.0	43.7	85.4	49.6	14.8
19	37.9	73.7	41.3	76.2	68.6	13.2
20	34.4	68.5	36.5	83.1	51.1	26.4
21	32.5	64.4	42.1	69.8	47.6	15.8
22	41.0	58.4	44.8	73.5	53.6	21.5
23	39.6	73.1	36.9	76.0	62.8	21.0
24	38.4	76.1	45.4	86.1	55.0	19.1
25	45.2	67.3	44.0	92.2	68.5	18.1
Operator Rating	***100***	***100***	***100***	***100***	***100***	***100***
MEAN RUN TIME PER CYCLE (sec)	**38.4**	**67.9**	**41.3**	**79.7**	**62.0**	**17.7**

Equipment Improvements

Equipment	Qty	Hrs	Watts	kWh/Day	Price/Day	Price/Mo	Price/Yr	Improvement	Percentage
Desktop Computer	8	16.90	300	40.56	$4.06	$89.23	$1,070.78		
*Desktop Computer	8	10.20	300	24.48	$2.45	$53.86	$646.27	$424.51	39.6%
Monitors	8	11.40	200	18.24	$1.82	$40.13	$481.54		
*Monitors	8	6.80	200	10.88	$1.09	$23.94	$287.23	$194.30	40.4%
Refrigerator	2	12.80	540	13.82	$1.38	$30.41	$364.95		
*Refrigerator - GE (Energy Star)	2	n/a	n/a	n/a	$0.37	$8.18	$98.16	$266.79	73.1%
3.5 Ton Central AC (10 SEER)	1	7.80	4200	32.76	$3.28	$72.07	$864.86		
*2.5 Ton Central AC (15 SEER)	1	7.80	2000	15.60	$1.56	$34.32	$411.84	$453.02	52.4%
Stock Room Flourescent	24	10.20	40	9.79	$0.98	$21.54	$258.51		
*Stock Room Flourescent	24	0.80	40	0.77	$0.08	$1.69	$20.28	$238.23	92.2%
Tablesaw Metal	1	2.30	5500	12.65	$1.27	$27.83	$333.96		
*Tablesaw Metal	1	1.96	5500	10.75	$1.08	$23.66	$283.87	$50.09	15.0%
Tablesaw Wood	1	2.20	4500	9.90	$0.99	$21.78	$261.36		
*Tablesaw Wood	1	1.87	4500	8.42	$0.84	$18.51	$222.16	$39.20	15.0%
Belt Sander	1	2.70	3500	9.45	$0.95	$20.79	$249.48		
*Belt Sander	1	2.30	3500	8.03	$0.80	$17.67	$212.06	$37.42	15.0%
Jointer	1	1.40	750	1.05	$0.11	$2.31	$27.72		
*Jointer	1	1.19	750	0.89	$0.09	$1.96	$23.56	$4.16	15.0%
Compressor Large	1	13.00	7500	97.50	$9.75	$214.50	$2,574.00		
*Compressor Large	1	9.10	7500	68.25	$6.83	$150.15	$1,801.80	$772.20	30.0%
Compressor Small	1	12.00	5250	63.00	$6.30	$138.60	$1,663.20		
*Compressor Small	1	8.40	5250	44.10	$4.41	$97.02	$1,164.24	$498.96	30.0%
Planer 1	1	1.30	6000	7.80	$0.78	$17.16	$205.92		
*Planer 1	1	1.11	6000	6.63	$0.66	$14.59	$175.03	$30.89	15.0%
Planer 2	1	1.10	4500	4.95	$0.50	$10.89	$130.68		
*Planer 2	1	0.94	4500	4.21	$0.42	$9.26	$111.08	$19.60	15.0%
Dust Collector 1	1	4.80	3500	16.80	$1.68	$36.96	$443.52		
*Dust Collector 1	1	4.32	3500	15.12	$1.51	$33.26	$399.17	$44.35	10.0%
Dust Collector 2	1	2.10	2250	4.73	$0.47	$10.40	$124.74		
*Dust Collector 2	1	1.89	2250	4.25	$0.43	$9.36	$112.27	$12.47	10.0%

[box] = **Location of Adjustment**
* = **Improved Equipment**

Total Savings Per Month **$257.19**
Total Savings Per Year **$3,086.22**

Figure 4 - Improvement Savings Calculations

Appendix B

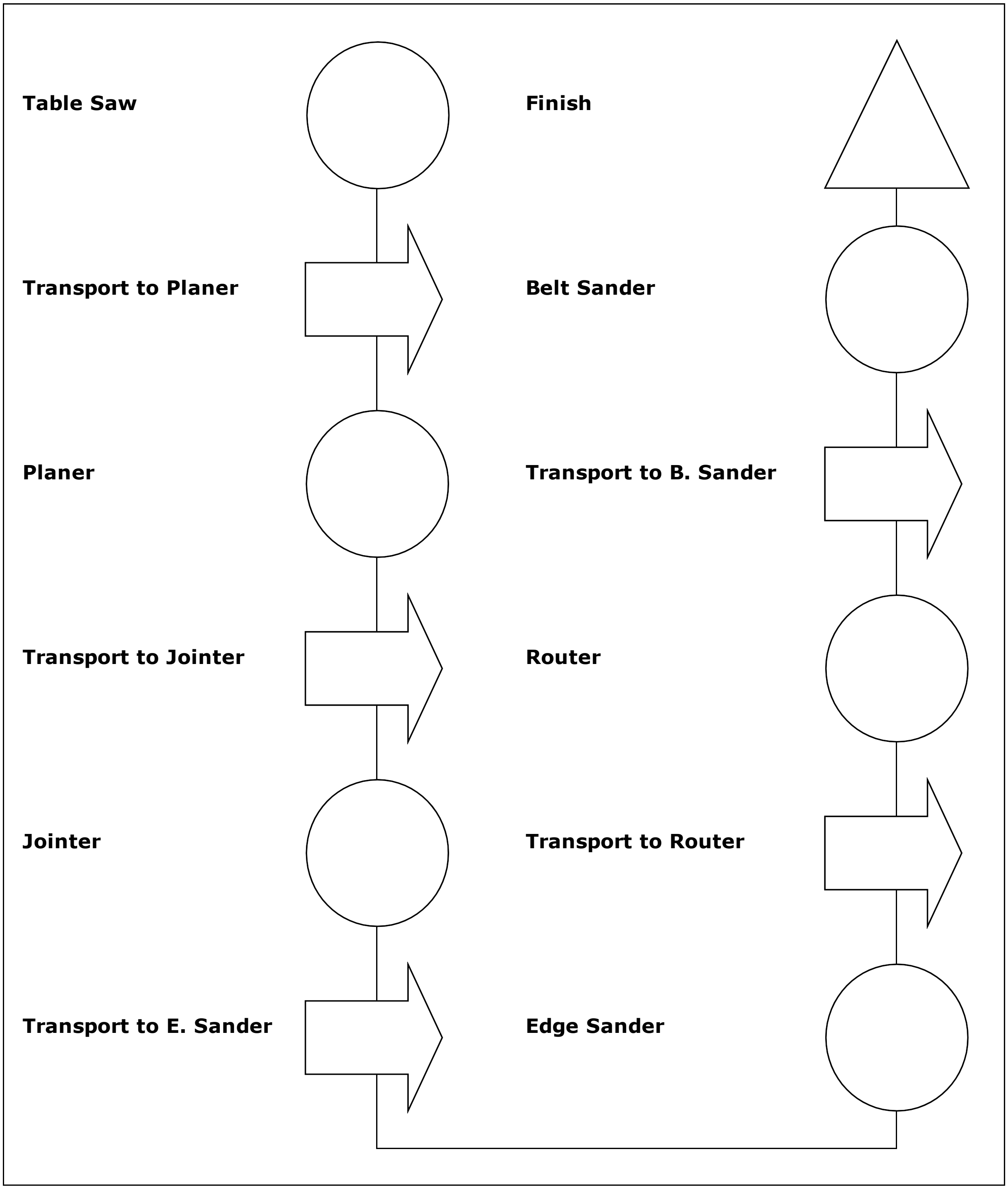


Figure 5 - Flow Process Chart: Manufacturing Overview

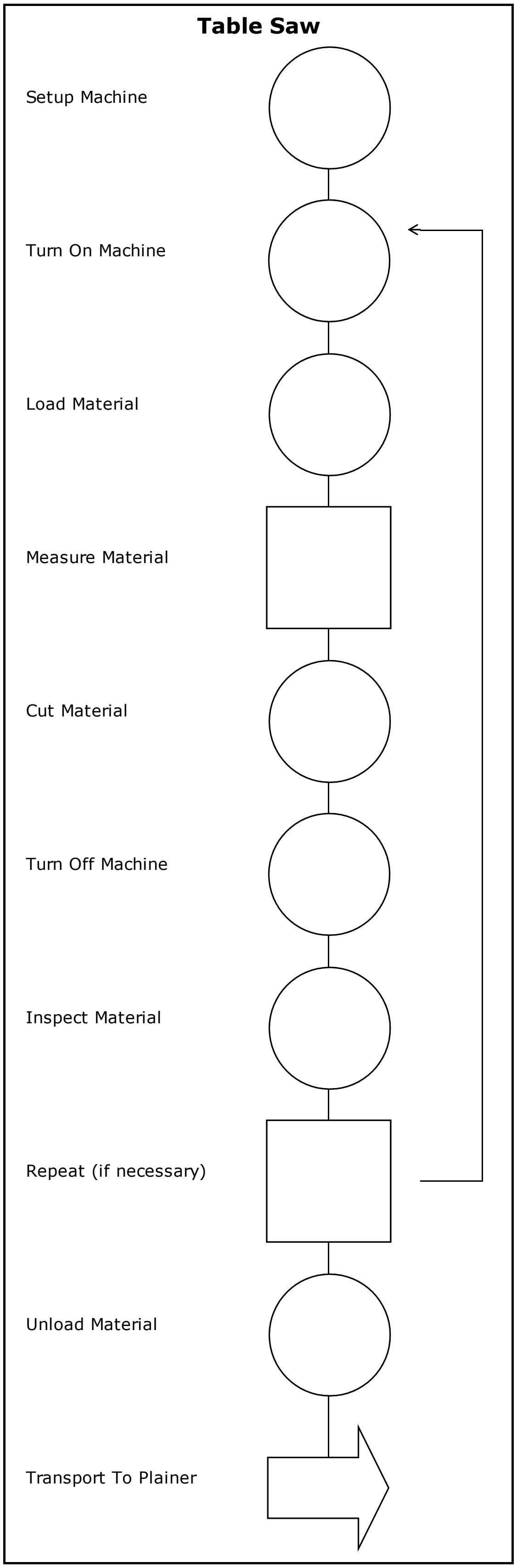


Figure 6 - FPC: Improved Table Saw

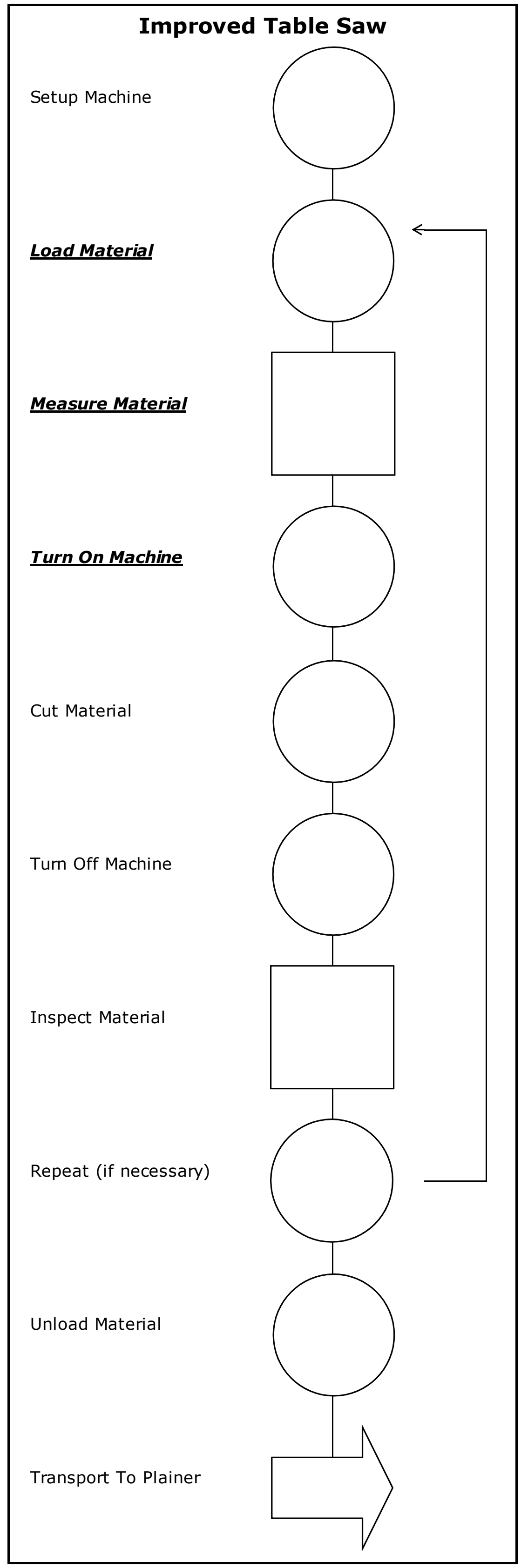


Figure 6 - FPC: Improved Table Saw

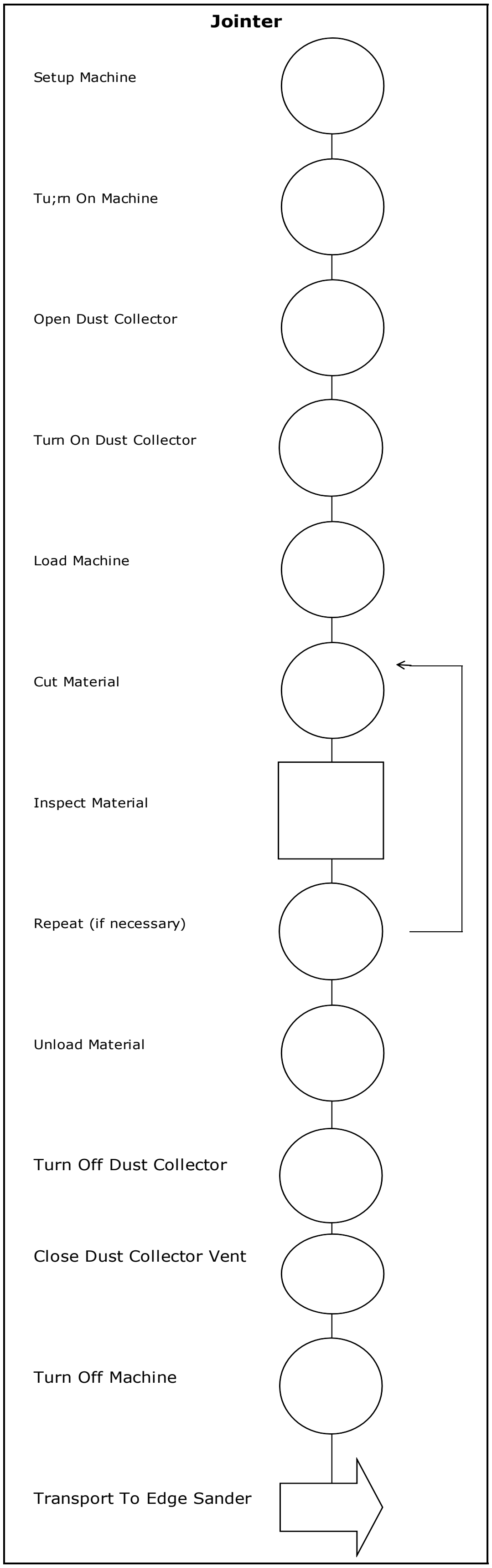


Figure 7 - FPC: Planer

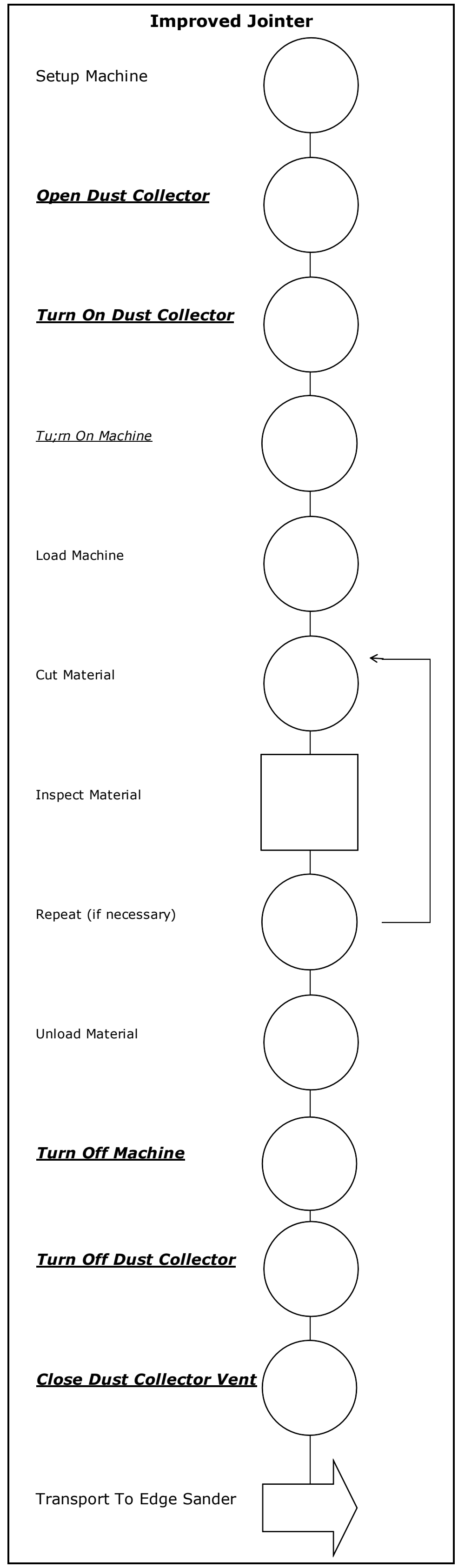


Figure 8: FPC: Improved Planer

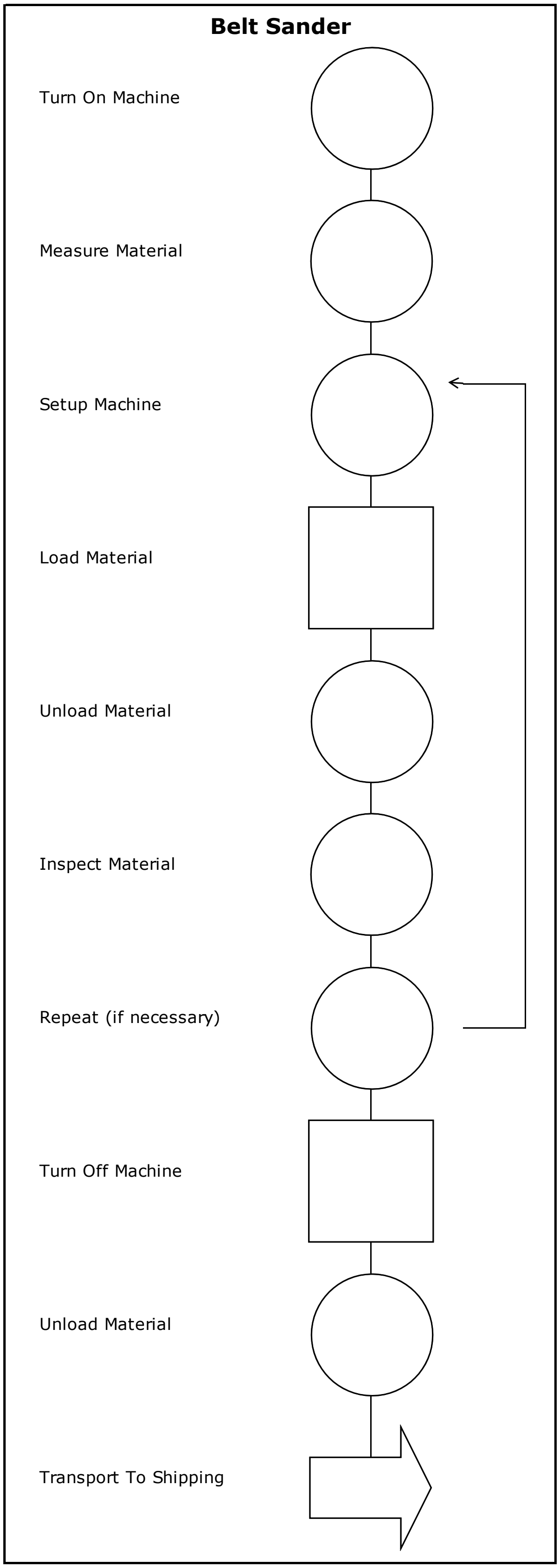


Figure 10- FPC: Belt Sander

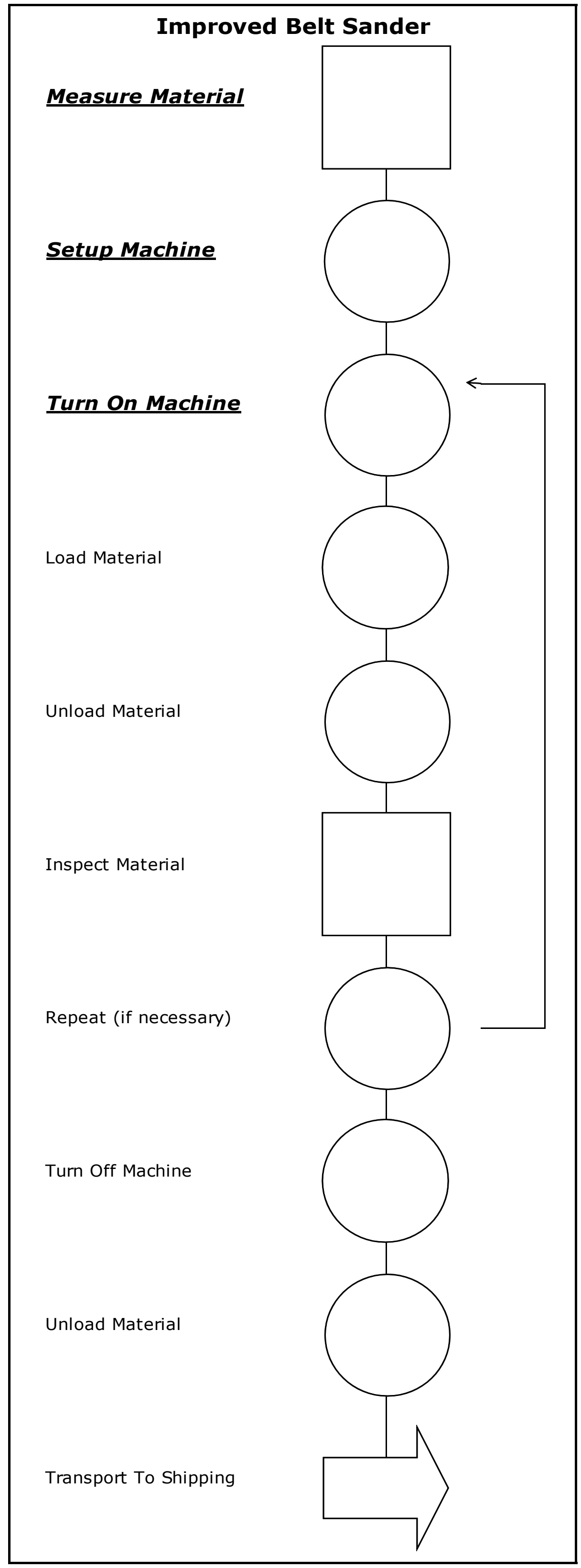


Figure 11 - FPC: Improved Belt Sander

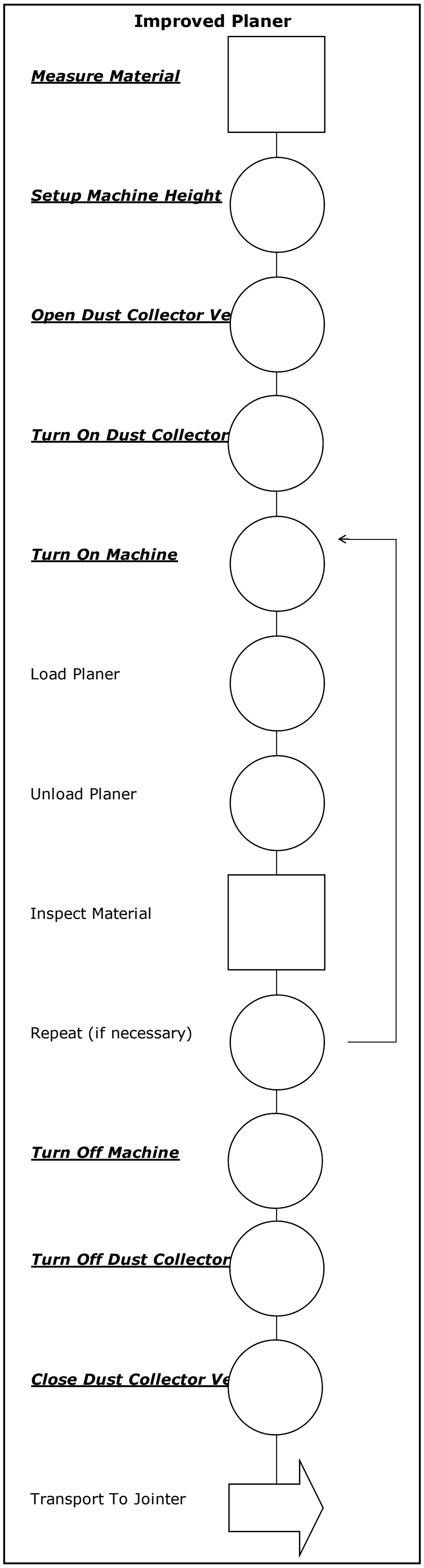


Figure 12– FPC: Improved Planer

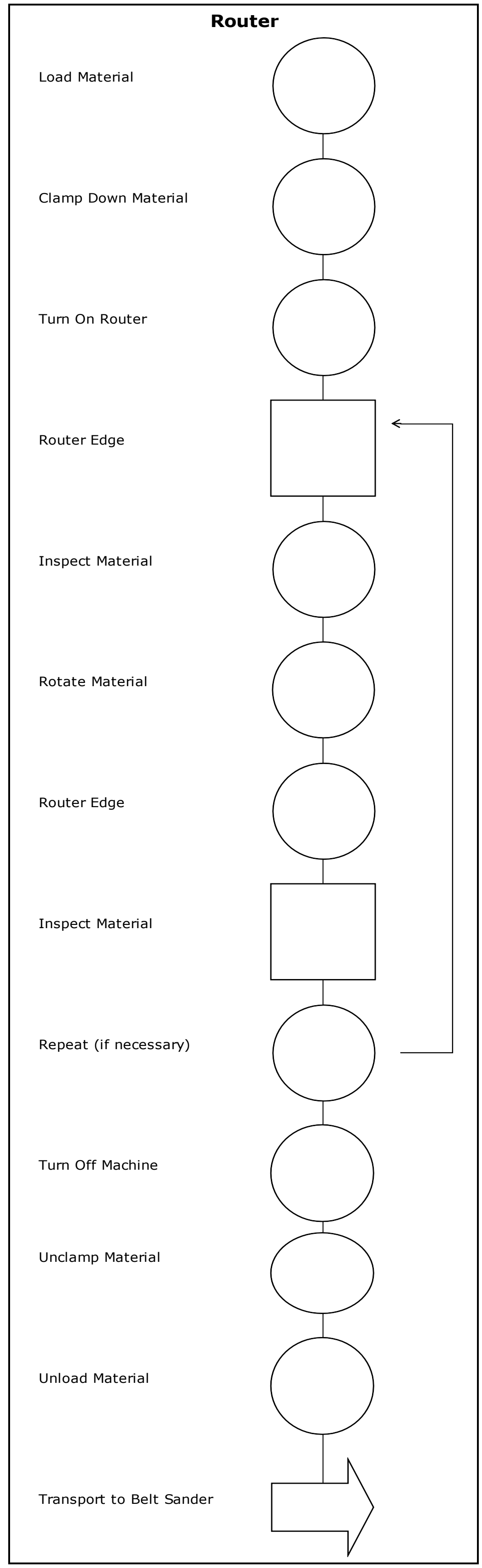


Figure 13- FPC: Router

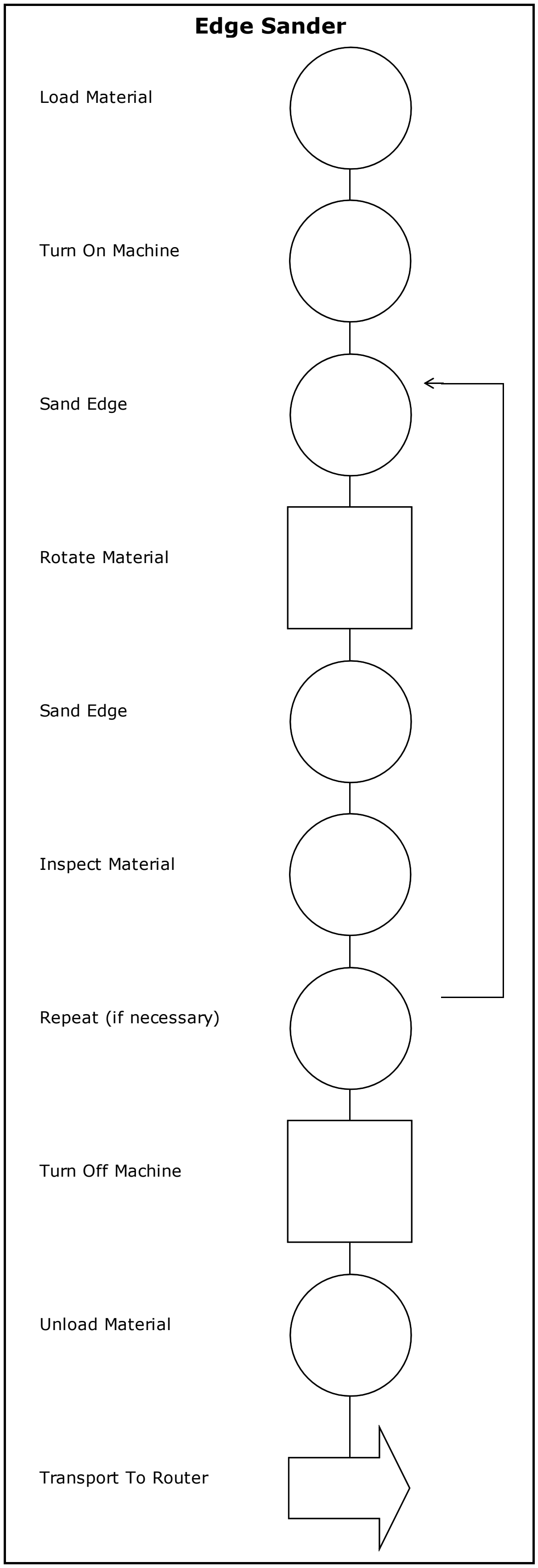


Figure 14- FPC: Edge Sander

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